DECLARATION OF LAWRENCE G. HOPKINS
March 15, 2005

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
PATENT APPLICATION EXAMINING OPERATIONS

Applicant:	Hopkins	Group Art Unit:	3745
Serial No.:	10/806,775	Examiner:	Nguyen, Ninh H.
Filed:	March 22, 2004	Docket No:	Hunt:FanArr1
Title:	Fan Array Fan Section in Air-Handling Systems		

DECLARATION OF LAWRENCE G. HOPKINS
UNDER 37 CFR SEC. 1.132

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March 15, 2005

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

I, Lawrence G. Hopkins, hereby declare as follows:

1. I am an engineer specializing in the fields of fan design, acoustics, vibration, and aerodynamics with particular emphasis in commercial and industrial air handler and ventilation equipment. I received a Bachelors of Science degree in mechanical engineering from The University of Portland in 1975 and became a registered engineer in the State of Oregon in 1982. I have 30 years experience in the fields of acoustics and vibration and 19 years experience in fan and air handling system design. I have worked in the industry in various capacities over the years ranging from engineer to engineering director for three multinational corporations. I directed the construction of two AMCA (Air Movement and Control Association) test facilities each designed and dedicated to the measurement and quantification of fan performance in the areas of air flow rate, consumed power, pressure, efficiency, vibration, sound, and

structural integrity. I am a member of the Institute of Environmental Engineers, Acoustical Society of America and the American Society of Heating Ventilation Engineers.

2. In 2002, I conceived initial embodiments of the present Fan Array Fan Section in Air-Handling Systems invention as a means of providing a fan system with features and benefits far exceeding present technology. The unique array and controller have also had substantially improved results over prior art devices (such as the AAON device) that would have been unexpected to one skilled in the art. The fan array outperforms current technology by a) demonstrating lower energy consumption for a given air delivery requirement, b) increasing system efficiency under steady and diversified loads, c) increasing system reliability to n+1 or greater redundancy, and d) significantly lowering noise levels.

a) The fan array outperforms traditional systems by allowing air entering or leaving the fan section to do so in a laminar manner thus eliminating stratification on upstream and downstream elements. Upstream and downstream elements may include filters, cooling and heating coils, sound attenuators, and humidification racks. Laminar air flow not only improves the efficiency of the individual devices but reduces pressure drop which reduces fan load and consumed power. In many traditional systems, settling means are installed between the inlet and discharge of the fan and surrounding elements to emulate laminar air flow. The settling means adds pressure drop to the system and causes power consumption to increase for a given air delivery requirement.

b) A fan array lowers energy consumption by allowing the designer to tailor the fan system output to the actual operating point of the process. It is general practice that all fan systems are designed for a worst case scenario. The worst case scenario is based on the greatest demand period which is a combination of coldest or warmest day of the year and loading parameters for filters and coils. It also includes safety factors applied to the design by the design engineer. The result is that nearly every air handler manufactured specified, manufactured, and put into service is over-designed for the normal operating condition. The excess design factors can be as high as 30% to 40% resulting in air handling systems that run at reduced efficiency. Fans

and motors are most efficient at one load point at a given speed. Motors are most efficient when nearly fully loaded. The fan wall allows the operator to turn off fans when they are not needed thus maintaining optimal motor efficiency and lower power consumption.

c) Unlike traditional air handler systems that require a complete shutdown to repair a motor failure, the fan array of the present invention is designed to operate and maintain system air with one or more motors off and to allow replacement of the damaged motor without turning the air handler off. This "hot repair" feature is unique to the fan array of the present invention and has proven to be exceedingly valuable to institutions or processes requiring stable delivery of conditioned air. Such industries include hospitals, semiconductor manufacturing plants, and pharmaceutical plants. A failure in the air handling system in process critical systems can result in loss of process control and reduced yield. A fan failure in a critical care facility may require evacuation or rescheduling of facility usage such as would occur for surgery units or areas mandating air delivery as a condition of occupancy. For highly critical spaces it is general practice to install two complete air handlers or install two complete fan systems in order to create what is known as n+1 redundancy. This is not the case with the fan array technology since any member of the fan array can repaired without disruption to the fan system as a whole. This provides 100% assurance that the system will remain stable and not affect critical functions.

d) Fan systems generate higher sound levels when operating at other than peak efficiency. Since the efficiency of the fan array of the present invention can be optimized for a larger range of operating points, the array will produce significantly lower sound levels than traditional systems. This coupled with close fitting insulation elements enables the fan array to outperform traditional systems by as much as 16 dB in the 63, 125, and 250 Hz octave bands. Equivalent reductions in traditional systems would necessitate the use of 7 to 10 foot long sound attenuators each causing a system pressure load and higher power consumption. In many cases the fan array can operate without the need for additional sound attenuation or corresponding pressure requirement.

3. Between my conception and March 20, 2003 (my priority filing date), I was actively involved in testing and development of the product including developing various embodiments thereof. The claimed invention was not patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the priority date.

4. I have reviewed the references submitted concurrently herewith in my INFORMATION DISCLOSURE STATEMENT. These references will be discussed jointly as the "AAON references." The AAON references disclose a fan system (AAON RL Series air handlers) having up to four fans. For the AAON RL Series air handlers, AAON allows the customer/designer to select from 1 to 4 supply fans ranging in size from 27" to 42.5" in diameter and return fans from 36" to 48" in diameter. AAON offers five unit sizes with pre-designed cabinet dimensions. The fan section length for any size or capacity offered is set at a predetermined length regardless of number of fans or fan size. Dimensional drawings included in the AAON application manual show the airway length for the fan section to be a minimum of 75.5" long to 90" long depending on the model.

5. As compared to the AAON RL Series air handlers, the fan array of my invention is based on using a larger quantity of smaller fans to compress the airway length and reduce overall unit size. The AAON application literature and accompanying software prohibit the customer/designer from selecting smaller fans for the purpose of compressing airway length. Because the AAON references teach against the use of smaller fans, it would not be obvious to one skilled in the art to attempt to scale the fan array for the purpose of saving cabinet length and corresponding real estate within the occupied building.

6. The AAON references do not teach or suggest my claimed use of "six fan units." The AAON references disclose the use of one fan unit, two fan units, three fan units, or four fan units (including a 2x2 array of fan units). Nowhere in the AAON references is there any teaching or suggestion that more fan units are contemplated and I have no knowledge of the use of more than the four fan units by anyone in the industry until after my priority date.

7. It is also clear that AAON did not recognize any benefit to increasing the number of fans to six or greater for the purpose of fine tuning the output or achieving higher efficiencies or creating redundancy or incorporating sound attenuating elements. In the AAON design, if one fan motor fails the air flow rate is reduced a minimum of 25%. In the example AAON job provided there are four supply fans each fitted with 25 horsepower motors (19.98 HP required at the operating point) operating at 1580 RPM producing 52,000 cfm. If one fan is turned off or fails, the new maximum flow rate for the unit is determined by speeding the remaining motors up to the maximum motor horsepower. The new maximum flow rate is 47,073 cfm at 1679 rpm at the maximum available power of 25 brake horsepower. Further, the AAON manual forces the user to pick motors based on fan size and duty that will not allow the system to maintain or recover air flow in the event of a motor failure. The AAON system static efficiency at full flow with four fans operating is 67.32% whereas a nine fan array can be configured to run at 72.4% static efficiency using 10 HP motors. Further the nine fan array can be configured to operate with eight fans while maintaining 52,000 cfm at the required pressure of 6.57" tsp while consuming 9.3 brake horsepower at 72.2% static efficiency. Even though one fan is off, the remaining eight fan array will maintain design flow rates while an AAON system with one fan off cannot maintain design flow rates (they actually drop in flow as they overload the motors). It is particularly interesting to note that Cleanpak, along with many other Huntair competitors, went on record criticizing my fan array as something "that would not work." Various publications emerged that contained language raising doubt as to the viability of a fan array. These publications would be available upon request.

8. The AAON references do not teach or suggest my claimed "array controller" for controlling the fan units "to run at substantially peak efficiency by strategically turning selective ones of said at least nine fan units on and off." The AAON references use an array controller that is limited to operating four fans over a limited range. The size of fans available and limited resolution in terms of each fan contribution prohibit the AAON system from functioning in a manner to capture the benefits of the claimed invention. Changes to the AAON array controller scheme or number of fans will

not achieve the same benefits as the claimed fan array. Therefore it would not be obvious to attempt a modification to the controller or fan design to achieve peak efficiency, nor would it be obvious to expect the fan array in the AAON design to function to maintain set flow rates in the event of a fan motor failure or to be able to achieve peak efficiency at with fewer fans.

9. The unique array and controller have solved an unsolved need of a fan system that can be optimized over a wide variety of conditions while offering unprecedented reliability and ease of maintenance. The fan array, by virtue of a reduced airway length, enables building owners to decrease the size of the equipment mechanical room and achieve more usable space or not over build mechanical space to accommodate large air handling systems. The fan array, because of its smaller size, saves on nonrenewable resources such as steel, insulation materials, and energy.

10. In large part because of my unique array and controller, Huntair (the assignee of the present application) has had significant commercial success as is shown in the accompanying power point presentation (Appendix A) and attached specification sheets taken from recent projects (Appendices B-D). The three specification sheets show three projects (out of many) that specify the Huntair fan array as the only allowed fan system. The three referenced projects include; The Sacramento LDS Temple in California (Appendix B), the Faribault Middle School in Minnesota (Appendix C), and the Phoenix Symphony Hall Renovation Project in Arizona (Appendix D). Each of these specifications explicit specify the Huntair Fan Wall Array as the only acceptable fan system for the project. More examples of sole sourcing the fan array are available on request. A further example of the popularity of the fan array is in critical process facilities such as the new Intel Fab 24.2 expansion in Ireland. Intel expedited a white paper to enable the fan array concept to be used on the new expansion. In this example the fan array was built and tested to show a reduced power consumption of 50% over the traditional system employed in phase 1. In a further example of the popularity of the fan array, Legacy Hospital reduced the number of air handlers from two to one by selecting the Huntair fan array.

11. I also have specific knowledge that Huntair's competitors are copying my unique array and controller. For example, Cleanpak International copied the fan array and presented concepts and designs to Intel on a recent data center project in Oregon. Cleanpak was ultimately awarded a contract based on price and a fan array that is identical to my fan array. A Technical Bulletin showing evidence of copying is attached as Appendix E. Additional evidence of copying was submitted along with the Petition to Make Special.

I further declare that all statements made herein are of my own knowledge, are true, and that all statements made on information and belief are believed to the true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Dated: March 15, 2005

Lawrence G. Hopkins

Appendix B

1. . an Wall Technology (FWT)

a. The Fan Wall Array, as manufactured by Huntair Inc., shall consist of multiple, direct driven, arrangement 4 plenum fans constructed per AMCA requirements for the duty specified, (Class II,). All fans shall be selected to the design air flow at the specified operating TSP at synchronous motor speed as specified and scheduled. The Fan Wall Array shall be selected to operate at a system Total Static Pressure that does not exceed 90% of the specified fan cartridge peak static pressure producing capability. Each fan/motor cartridge shall consist of an 11 gauge A60 galvanized steel intake wall, 14 gauge spun steel inlet tunnel, and 11 gauge A60 galvanized steel motor support plate and structure. The fan cartridge intake wall, inlet funnel fan wheel, and motor support structure shall be powder coated. All motors shall be standard T-frame motors selected at the specified operating voltage and RPM, and efficiency as specified elsewhere. Entire assembled fan/motor cartridge shall not exceed 165 lbs in total weight unless otherwise specified. Each fan/motor cartridge shall be dynamically balanced to meet AMCA standard 204-96, category BV-5, Grade 1.0 with peak to peak deflection equal to or less than .5 mil at the design operating speed for the fan/motor cartridge.

b. The fan array shall consist of multiple fan/motor "cartridges", spaced in the air way tunnel cross section to provide a uniform air flow and velocity profile across the entire air way tunnel cross section and components contained therein. Each fan cartridge shall be individually factory wired to a factory installed control panel containing two VFDs, sized for the total connected HP for the Fan Wall Array. Wire sizing shall be determined in accordance with NEC standards. Control panel shall be factory installed on the air handling unit with single point power connection.

c. The Fan Wall array shall produce a uniform air flow profile and velocity not to exceed the specified cooling coil and/or filter bank face velocity when measured at a point 12" from the intake side of the Fan Wall array septum wall, and at a distance of 42" from the discharge side of the Fan Wall array septum wall.

d. Each fan/motor cartridge shall be removable through a 30" wide access door located on the discharge side of the fan wall array.

e. The manufacture shall provide a complete spare FWT fan/motor cartridge for emergency replacement, one for each type of assembly provided on the project.

f. Individual fans shall not exceed 0.025" per second at the rotational speed of the wheel. Further the sum of all the fans shall not exceed 0.025" per second measured at the fan section base.

g. Furnish with factory installed straightening grid, coplanar silencer on outlet side of fan, and outlet gravity backdraft damper at each fan.

h. Furnish each fan with "flow-cone" airflow measuring with digital read out display showing total of all fan CFMs. Digital read out shall be factory wired. Locate display in the face of the unit mounted control panel.

C. Motors

1. Fan motors as specified in Section 15055. Premium efficiency, inverty duty. Match motor with variable frequency drive. All motor bearings shall be electrically isolated from the motor housing.

D. Coils

1. Provided by same company as supplier of air handling units and designed with aluminum plate fins and copper tubes, with stainless steel casings.

2. Fins shall have collars drawn, belled, and firmly bonded to tubes with mechanical expansion of tubes. Fins shall be minimum 0.01" sheet thickness.

a. Soldering or tinning shall not be used in bonding process.

b. Mount coils in unit casing to be accessible for service and can be removed from unit through side or top.

c. Capacities, pressure drops, and selection procedure shall be certified in

Appendix C

size and location where shown on plans. An ETL rated fan access door latch shall be installed on all fan modules. Access handles shall accept a lock.

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8. Condensate Drain Pans: Formed sections of stainless-steel sheet or galvanized steel coated with microbial resistant Fosters 40-60 or equal product complying with requirements in ASHRAE 62. The entire drain pan shall be insulated under the entire coil section as wee as coil headers. The entire drain pan shall be visible for downstream inspection. Provide a drain a minimum centerline of 3" above the base rail.
9. Units with stacked coils shall have an intermediate drain pan or drain trough to collect condensate from top coil.

2.3 FAN WALL SECTION

A. The Fan Wall System, as manufactured by Huntair Inc., shall consist of multiple, direct driven, arrangement 4 plenum fans constructed per AMCA requirements for the duty specified. All fans shall be selected to deliver the specified airflow quantity at the specified operating Total Static Pressure and specified fan/motor speed. The Fan Wall Array shall be selected to operate at a system Total Static Pressure that does not exceed 90% of the specified fan's peak static pressure producing capability at the specified fan/motor speed.

B. Each fan/motor cube shall include an 11 gauge, A60 Galvanized steel intake wall, 14 gauge spun steel fan inlet funnel, and an fully welded structural steel angle iron frame designed to support a pedestal mounted arrangement 4 direct drive fan/motor assembly.

C. The fan intake wall, inlet funnel, and motor support structure shall be powder coated for superior corrosion resistance.

D. All motors shall be standard pedestal mounted type, ODP, T-frame motors selected at the specified operating voltage, RPM, and efficiency as specified or as scheduled elsewhere. All motors shall include isolated bearings or shaft grounding. Each fan/motor cartridge shall be dynamically balanced to meet AMCA standard 204-96, category BV-5, to meet or exceed Grade 2.5 residual unbalance.

E. The FWT array shall be provided with coplanar acoustical silencers that reduce the bare fan discharge sound power levels by a minimum of 15 db re 10^-12 watts throughout the eight octave bands with center frequencies of 125, 250, 500, 1000, 2000, 4000, and 8000 HZ when compared to the same unit without the silencers. The silencers shall not increase the fan total static pressure, nor shall it increase the airway tunnel length of the Air Handling Unit when compared to the same FWT unit without the silencer array.

F. Manufacturer must submit acoustical data for review and approval prior to the bid indicating that the proposed equipment can meet all specified performance requirements without impacting the equipment performance or design features including duct connection location, unit weights, acoustical performance, or specified total fan HP for each FWT array. Proposals submitted which indicate a higher connected fan HP than specified or scheduled will not be accepted.

G. The fan array shall consist of multiple fan and motor "cubes", spaced in the air way tunnel cross section to provide a uniform air flow and velocity profile across the entire air way tunnel cross section and components contained therein. Each fan cube shall be individually wired to a control panel containing a single VFD, as specified elsewhere, for the total connected HP for all

2 contd.

fan motors contained in the FWT array. Wire sizing shall be determined, and installed, in accordance with applicable NEC standards.

H. The Fan Wall array shall produce a uniform air flow profile and velocity profile within the airway tunnel of the air handling unit not to exceed the specified cooling coil and/or filter bank face velocity when measured at a point 12" from the intake side of the Fan Wall array intake plenum wall, and at a distance of 48" from the discharge side of the Fan Wall intake plenum wall.

I. Each fan/motor assembly shall be removable through a 30" wide, free area, access door located on the discharge side of the fan wall array.

2.4 MOTORS

A. General: Premium Efficiency Inverter Duty Rated for variable speed operation and to comply with requirements in Division 15 Section "Motors."

B. Noise Rating: Very Quiet.

2.5 COILS

A. Coil Sections: Common or individual, insulated, galvanized-steel casings for coils. Design and construct to facilitate removal and replacement of coil for maintenance and to ensure full airflow through coils. Provide access from both sides of coil.

B. Water Coils: Coils shall be fully drainable and cleanable. Coils shall be ARI 410 certified and UL listed.

1. Piping Connections: Threaded on same end. Connections shall be on the side shown on the drawings.
2. Tubes: Tubes shall be 5/8" outer diameter, minimum of .020" thick brazed seamless copper on 1-1/2" centers, staggered in the direction of airflow. Tubes shall be mechanically expanded into the fins to provide continuous primary to secondary compression bond over the entire finned length to maximize heat transfer. Bare copper tubes shall not be visible between fins.
3. Fins: Aluminum plate construction with a minimum thickness of 0.0075 inch and shall not have more than 12 fins per inch. Fins shall have full drawn collars to provide continuous surface to cover over the entire tube for maximum heat transfer.
4. Headers: Headers shall be seamless copper tubing with intruded tube holes that permit expansion and contraction without undue stress or strain. Headers to be fully inclosed with in the unit casing.
5. Venting: Coils shall have factory vent connections at the highest point. Drain connections shall be provided at the lowest point.
6. Provide airtight grommets to avoid casing leakage and comply with ASHRAE indoor air quality standards.

2.6 DAMPERS

A. General: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm face velocity through damper and 4-inch wg pressure differential.

Appendix D

1. As shown, Refer to Detail drawings:

D. Condensate Drain Pans: Formed sections of stainless-steel sheet complying with requirements in ASHRAE 62. Fabricate pans with slopes in two planes to collect condensate from cooling coils (including coil piping connections and return bends) when units are operating at maximum catalogued face velocity across cooling coil.

1. Double-Wall Construction: Fill space between walls with foam insulation and seal moisture tight.
2. Drain Connections: Both ends of pan.
3. Pan-Top Surface Coating: Elastomeric compound.
4. Units with stacked coils shall have an intermediate drain pan or drain trough to collect condensate from top coil.

2.4 FAN SECTION

A. Fan-Section Construction: Direct-drive axial fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure and equipped with formed-steel channel base for integral mounting of fan, motor, and casing panels. Mount fan with vibration isolation.

B. Centrifugal Fan Housings: Spun-metal inlet bell, and access doors or panels to allow entry to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting wheel, motor, and accessories.
2. Performance Class: AMCA 99-2408, Class I or II or III.
3. Plug Fans: With steel cabinet. Fabricate without fan scroll and volute housing.

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C. Fan Assemblies:

1. The fan system shall consist of multiple, direct driven, arrangement 4, plenum fans constructed per AMCA requirements for the duty specified, (Class I, II, or III). All fans shall be selected to deliver the specified airflow quantity at the specified operating Total Static Pressure and specified fan/motor speed. The Fan Wall Array shall be selected to operate at a system Total Static Pressure that does not exceed 90% of the specified fan's peak static pressure producing capability at the specified fan/motor speed. Each fan/motor "cube" shall include an 11 gauge, A60 Galvanized steel intake wall, 14 gauge spun steel inlet funnel, and an 11 gauge G90 Galvanized steel motor support plate and structure. The fan intake wall, inlet funnel, and motor support structure shall be powder coated for superior corrosion resistance. All motors shall be standard pedestal mounted type, TEFC T-frame motors selected at the specified operating voltage, RPM, and efficiency as specified or as scheduled elsewhere. All motors shall include isolated bearings or shaft grounding. Each fan/motor cartridge shall be dynamically balanced to meet AMCA standard 204-96, category BV-5, to meet or exceed Grade 2.5 residual unbalance.
2. The Fan Wall Array shall be provided with acoustical silencers that reduce the bare fan discharge sound power levels by a minimum of 15 db re 10^-12 watts throughout the eight octave bands with center frequencies of 125, 250, 500, 1000, 2000, 4000, and 8000 Hz when compared to the same unit without the silencers. The silencers shall not increase

the fan total static pressure, nor shall it increase the airway tunnel length of the Air Handling Unit when compared to the details shown on the drawings.

3. Alternate manufacturers must submit acoustical data for review and approval prior to the bid indicating that the proposed alternate equipment performance or design features including duct connection location, unit weights, acoustical performance, or specified total fan HP.
4. The fan array shall consist of multiple fan and motor "cubes", spaced in the air way tunnel cross section to provide a uniform air flow and velocity profile across the entire air way tunnel cross section and components contained therein. Each fan cube shall be individually wired to a control panel containing a single VFD, as specified elsewhere, for the total connected HP for all fan motors contained in the fan wall array. Wire sizing shall be determined, and installed, in accordance with applicable NEC standards.
5. The fan wall array shall produce a uniform air flow profile and velocity profile within the airway tunnel of the air handling unit not to exceed the specified cooling coil and/or filter bank face velocity when measured at a point 12" from the intake side of the fan wall array intake plenum wall, and a distance of 48" from the discharge side of the fan wall intake plenum wall.
6. Each fan/motor assembly shall be removable through a 30" wide, free area, access door located on the inlet side of the fan wall array.
7. Each fan assembly shall be supplied with a complete flow measuring system, which indicates airflow in Cubic Feet per Minute. The flow measuring system shall consist of a flow measuring station with four static pressure taps and four total pressure tubes located at the throat of the fan inlet cone. The flow measuring station shall not obstruct the inlet of the fan and shall have no effect on fan performance (flow or static) or sound power levels. A surface mounted indicator, located on the unit exterior, shall provide a digital CFM readout, and a 4-20 mA output control signal for use in the BAS as specified elsewhere.
8. The manufacturer shall provide a complete spare fan/motor assembly for emergency replacement, one for each type of assembly provided on the project. Manufacturers for alternate, single direct driven fan assembly provided in lieu of the specified fan wall shall provide a spare motor and fan assembly and a five year, parts and labor warranty for repair and/or replacement at no additional expense to the owner. Such warranty coverage shall include all freight charges for expedited shipment of emergency replacement parts, the cost of any cranes or lifting devices, and any costs associated with air handling unit disassembly and re-assembly, as required, for emergency replacement of any defective fan or motor.

D. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, L_{10} of 50,000 hours.
2. Ball-Bearing Rating Life: ABMA 9, L_{10} of 50,000 hours.

E. Vibration Control: Install fans on open-spring vibration isolators having a minimum of 1-inch static deflection and side snubbers.

F. Fan-Section Source Quality Control:

1. Sound Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300,

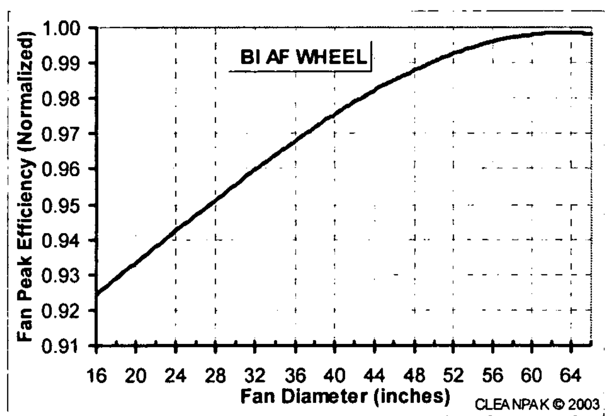
Appendix E

Technical Bulletin CLEANPAK MRPF
Multiple/Redundant Plenum Fan

The application of multiple fans in a common system, in part, provided the impetus of the design of the "plug" fan years ago. CLEANPAK International has incorporated multiple fans in common cabinets for several years to provide systems that require redundancy, to meet architectural profile requirements, and for space savings. The arrangements may be vertical up or down flow or horizontal. The notes below apply generally, but often relate to redundancy issues, which is a benefit of multiple fan operation whether a design requirement or not.

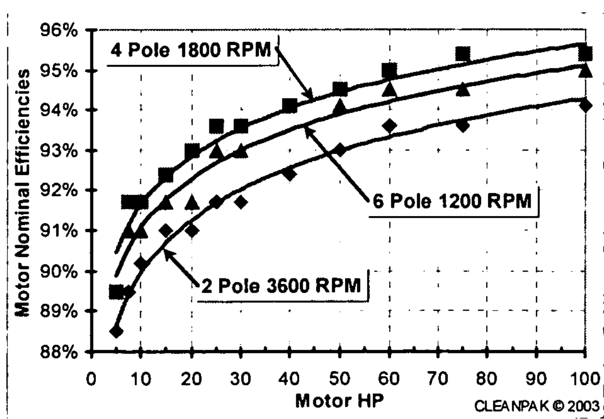
General
There are three general arrangements for multiple plenum fan configurations as noted below. Each arrangement has its benefits.
1+1: 2 fans can be provided in a cabinet with either fan capable of supplying 100% of the design flow requirement. This would provide 100% redundancy. Normal operation can be simultaneous or independent.
Twin: 2 fans can be provided in a cabinet with both fans required for the design flow. This arrangement provides capacity in excess of 50% if a single fan fails, since the system pressure drop falls by the square of the volume decrease. Additional capacity can be provided by ramping the VFD up to the limit of the motor full load amps. Normal operation is always simultaneous.
Xn+1: This system provides a measure of redundancy by providing a number of fans smaller than that required by the 1+1 arrangement. The failure of a single fan is accommodated by the initiation of an unused fan, or the ramp up of all remaining fans. The number of fans can be as high as 12-18, although it is not limited. Normal operation is always simultaneous.

Airflow Isolation
- Inlet or discharge isolation dampers with a solid dividing wall can be provided for fan service of an inoperative fan while operating at design flow for the 1+1 system. The damper pressure drop should be included in the calculation of the total static pressure (TSP).
- An Econo-Disk® may be provided for manual or automatic fan isolation for any of the applications, although as the fans become smaller (18" and under) performance penalties may result. Econo-Disk shutoff characteristics are excellent.
- Inlet isolation dampers can be provided and function similar to, but not as efficiently as, the Econo-Disk. Back draft dampers (heavy duty) can be used but may provide unstable operation at low flows. The damper pressure drop should be included in TSP calculations.
- If some sort of fan isolation is not provided, system performance will suffer a dramatic decrease with a fan failure, due to back flow through the failed fan.



Fan efficiencies are generally higher for larger size fans

Efficiency
- Larger diameter fans have significantly higher peak efficiencies than smaller diameter fans. Selecting fans at optimum efficiency for an operating point requires the ability to vary wheel width and operating speed.
- Larger motors are significantly more efficient than smaller motors.
- Motors operated at 75% full load are slightly more efficient than those that operate at 100% full load.

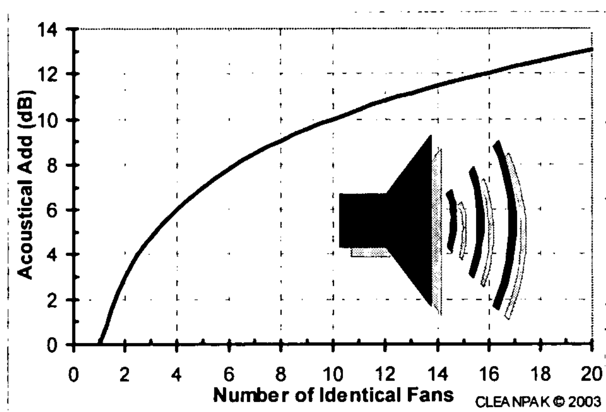


Motor efficiencies are higher for larger size motors

- System efficiency can be improved with internal and external pressure loss reductions such as low velocity coils and high capacity filters.

Dimensions
- For 1+1 systems, inlet and discharge plenum lengths may depend on the normal operating condition. Multiple fan configurations allow for more even velocity profiles for any given length than a single fan configuration.
- Larger fans take more airway length than smaller fans. Service access behind fans is similar for both large and small fans.
- Isolation dampers on the fan inlet increase the airway length.
- Isolation dampers on the fan outlet increase the airway length.
- Large numbers of fans operating as in Xn+1 can reduce the airway length compared to the 1+1 arrangement, particularly if the 1+1 design has an independent operating design rather than a simultaneous operating design.
- Unusual profiles may be accommodated with larger numbers of fans (Xn+1).

Pressure/Volume Control
- VFDs work well when the system follows the fan laws but do not work well if volume varies but the ESP is high and constant, or the fans operate with multiple volumes and constant pressure.
- The Econo-Disk can be used to provide volume control while maintaining design pressure with the simultaneous operation described in 1+1.
- Econo-Disks can be used for both volume and pressure control with manual, pneumatic, or electric actuation.
- Econo-Disks can be used with VFDs for increased flexibility and efficiency.
- Multiple fans such as Xn+1 can be staged and manipulated with VFDs and isolation dampers to offer constant pressure with variable volume.
- Multiple, simultaneous operating fans are generally operated at the same speed.
- Inlet isolation dampers can be used for volume control by "riding the curve" although this is not recommended since it is an inefficient method and may result in unstable operation.



Acoustical add for multiple sources

Sound
- Manufacturers' bare fan sound levels should be adjusted for multiple fan operation. Sound power levels are 11dB higher for 12 fans operating than for only one of the twelve.
- Smaller fans operate at higher speeds than larger fans for any given pressure. This shifts the primary tone of the fan (or blade passage frequency) to higher frequencies and may shift it to a higher octave band. Generally speaking this is advantageous in that higher frequencies are typically attenuated more easily.
- There is a potential for acoustical beats to arise with multiple fan systems.

Vibration Isolation
- 1+1 and twin fan operations are usually internally spring isolated.
- Xn+1 systems with stacked fans, racked, are usually provided without internal isolation, but can be internally spring isolated.

Service
- Smaller fans and motors are easier to physically manipulate than large fans and motors.

- Larger numbers of fans, motors, VFDs, dampers, and damper actuators increase service requirements and increase the potential points of failure.
- Generally a fan will be isolated until a system shutdown for major service, or if the fans are screened service is performed while one or more fans are operating.
- Service in an active air stream, without pressure and flow interference can be performed most easily with an airlock.
- Taperlock fan hubs offer quicker and simpler motor/fan wheel replacements than straight bore hubs.
- Bearing life is unaffected by the number of fans operating (1+1 or Xn+1), as the fewer fans use larger motors and bearings and operate at slower speeds.
- Aluminum wheels reduce the bearing load.
- Spare parts are less costly for small fans compared to larger fans.

Electrical

- 100% redundancy systems (1+1) require greater electrical service requirements than other systems but are as efficient or more efficient during operation.
- If single VFDs are used to run multiple motors, each motor requires separate overload protection. VFD to motor lead length is the sum of all the lead lengths fed by a single VFD.
- Multiple VFDs reduce the need for VFD bypass options.

Initial Cost

- $/CFM are lower for larger fans.
- $/HP are lower for larger motors and VFDs.
- Cabinet costs may be reduced with Xn+1 systems, due to the reduced cabinet length.

In the application of multiple smaller fans, one should consider several factors that affect initial cost, operating efficiency, redundancy, and reliability. The discussion above should help the designer evaluate the various options. Optimizing for single or multiple fan applications calls for flexibility from the air handling unit manufacturer. Please contact CLEANPAK's technical staff for further information and assistance with your application.